For submission to the Micromission Workshop, Paris, France, February 1-2, 1999

MICROSEISMOMETER FOR MICROMISSION APPLICATIONS

W. T. Pike and W. B. Banerdt
Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena CA 91109 USA

The measurement of the vibration of celestial bodies is one of the primary methods for determining their mechanical structure. At the planetary level, seismology has already successfully elucidated the internal structure of the Earth and Moon. A long-running goal of planetary exploration has been similarly to determine the internal structure of Mars. However, an unambiguous seismic survey of the global structure requires a long-lived network distributed across the planet. The 2005 Netlander mission plan envisages a small number of low-frequency seismometers, with a more extensive deployment of higher-frequency microseismometers.

Seismometers can also determine structure at a more local level, as used on Earth for surveying of petroleum reservoirs, and there are proposals for such a local seismic survey for buried liquid water deposits on Mars. For small objects, determination of the vibration spectrum from a single sensor can be used to determine the mechanical structure of the object. Such an application is being considered to determine the thickness of the ice layer that has been observed on Europa.

Common to all these applications is the need for small, robust, low-power seismometers with performance comparable to the present terrestrial seismometers, namely sensitivity to signals below 1 ng/•(Hz). In order to meet this sensitivity, terrestrial seismometers have used low-resonant-frequency suspensions, which have resulted in bulky, massive instruments that are extremely delicate. Raising the resonant frequency results in more compact seismometers but at the expense of sensitivity unless the self-noise of the sensing transducer can be dramatically improved. We have developed a position transducer suitable for incorporation into a differential capacitive microseismometer for planetary applications which not only has improved sensitivity but also consumes very little power. This low-power switched-capacitor transducer takes advantage of recent developments in low-power, low-noise CMOS amplifiers. The principle of operation is similar to the purely analog Blumlein bridge, with the switches producing a square-wave rather than the sinusoidal voltage of the Blumlein bridge across the sensor capacitors.

In order to obviate the need for a mechanical leveling mechanism, an electronic feedback scheme has been developed to center the moving capacitor plate between the fixed plates of the capacitance transducer. This has been achieved by separating the signal in the frequency domain to overcome the dynamic range problem of measuring nano-g-level signals on a large (~1 g) offset: the low frequency portion is used at reduced gain to center the capacitance sensor, while the high frequency signal, at high gain, provides the seismic information. The transition between the two regimes is set at 20 s in our implementation. The limits to performance are now set by the dynamic range of the amplifier to the feedback actuator.

The suspension is designed in silicon using micromachining techniques to achieve the tolerances required for an ultrasensitive capacitance sensor. The spring is fabricated from a 10-μm thick silicon membrane, bonded to a silicon proof mass using microwave-bonding techniques. Such bonding can also produce a vacuum seal; we have produced structures with leak rates below 10E-8 atm.cc/s. This vacuum is required to reduce the gaseous damping of the proof mass, raising the quality factor, Q, of the suspension, and hence reducing the noise floor of the sensor. A further advantage of silicon is, with proper design, its robustness to shock. Model suspensions have been carried by a microlander forebody during high-altitude drop tests, and have survived penetration. The low resource profile and robustness of the microseismometer being developed makes it a prime candidate for incorporation into a micromission payload.

The work described in this abstract was performed at the Center for Space Microelectronics Technology, Jet Propulsion Laboratory, California Institute of Technology, ~~*and was sponsored by*~~ under a contract *the National Aeronautics and Space Administration, Office of Space Science.*